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STRUCTURAL CHANGE, NATIONAL INNOVATION SYSTEM AND BALANCE-OF-PAYMENTS CONSTRAINT: A THEORETICAL AND EMPIRICAL ANALYSIS OF THE BRAZILIAN CASE

João Prates Romero
Fabrício Silveira
Gustavo Britto

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STRUCTURAL CHANGE, NATIONAL INNOVATION SYSTEM AND BALANCE-OF-PAYMENTS CONSTRAINT: A THEORETICAL AND EMPIRICAL ANALYSIS OF THE BRAZILIAN CASE

João Prates Romero
Master in Economics, CEDEPLAR/UFMG.

Fabrício Silveira
Master in Economics, CEDEPLAR/UFMG.

Gustavo Britto
CEDEPLAR/UFMG

CEDEPLAR/FACE/UFMG
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SUMÁRIO

RESUMO

Esse artigo é explora alguns dos nexos causais entre o desenvolvimento do Sistema Nacional de Inovação (SI), as elasticidades-renda da demanda do comércio exterior e crescimento econômico. Mais especificamente, procura-se mostrar como as diferenças nas taxas de crescimento do produto estão associadas a diferentes elasticidades-renda, que, por sua vez, são determinadas pelo grau de maturidade do SI. De acordo com a literatura, um SI maduro implicaria maior diversificação da produção nacional, com reflexos diretos na pauta comercial, favorecendo ainda a exportação de bens com maior conteúdo tecnológico – de alta elasticidade-renda – e a importação de bens mais básicos – de baixa elasticidade-renda. Dessa forma, testamos a relação entre as exportações e importações brasileiras de produtos tecnológicos e as patentes brasileiras registradas no USPTO, como proxy para o desenvolvimento do SI brasileiro. Os resultados da análise são corroborados pela investigação de inovações no modelo, através de funções de impulso-resposta e decomposição dos erros de previsão, confirmando a hipótese teórica apresentada.

Palavras-chave: Restrição Externa, Elasticidades, Crescimento, Mudança Estrutural, Sistema Nacional de Inovação.

JEL: F43, L16, O11

ABSTRACT

The paper explores the relationship between the income elasticities of demand for exports and for imports, economic growth, the technological content of local production, and the level of development of the National Innovation System (NIS). According to the literature, differences in long-run growth rates are associated with differences in the income elasticities of demand, which would in turn be determined by the maturity of the NIS. Mature NIS imply higher degrees of product diversification, leading to trade patterns which favour exports of goods with higher technological content (high income elasticity of demand), and imports of basic goods (low income elasticity). Hence, we test the relationship between the exports and imports of Brazilian high-tech products and the number of Brazilian patents registered in the USPTO, as a proxy for the level of development of the Brazilian NIS. The results of the analysis are corroborated by the investigation of innovations of the variables, through impulse response functions and forecast error decomposition, which confirm the theoretical hypothesis discussed.

Key-words: Balance-of-Payments Constraint, Income Elasticities, Growth, Structural Change, National Innovation System.

JEL: F43, L16, O11

1. INTRODUCTION

For over half a century, Structuralist, Keynesian and Kaldorian authors have been studying the importance of the income elasticities of demand for imports and for exports for economic development and long-term growth rates. The recurring confirmation of the link between a country's productive structure, its pattern of trade and its long-term growth rate has led to a growing interest in the determinants of the trade elasticities. By reflecting supply side factors which are inextricably linked with the possibility of success in international trade, the demand-elasticities of trade incorporate competitiveness elements not adequately captured by the prices of traded goods[1].

In this debate, product differentiation and increased quality are decisive components of non-price competitiveness, which explain exports and intra-industry trade growth (McCombie & Thirlwall, 1994). Thus, changes in the productive structure related to shifts of the trade pattern can lead to substantial commercial gains, if sectors and products of greater income elasticity of demand increase their relative share in the traded goods. In line with this argument, Araújo & Lima (2007) and Gouvêa & Lima (2010) demonstrated that shifts of the productive structure favouring sectors of greater technological intensity are associated with increases of the income elasticity of demand – and, consequently, to different growth rates of the GDP. This relationship suggests that, from a long-term perspective, an important part of the countries' growth can be explained by elements dear to the Schumpeterian tradition. Recent works are thus attempting to establish theoretical links between the Keynesian, Kaldorian, Structuralist and Schumpeterian perspectives. More specifically, some authors have proposed that the maturity of a country's National Innovation System (NIS) is interrelated with the possibility of a structural change associated with more dynamic patterns of trade[2].

The aim of this paper is to present a twofold contribution to the debate. Firstly, we intend to establish theoretical links between the mentioned schools of thought, demonstrating the connections between external vulnerability, competitiveness (income elasticity of demand for exports and for imports) and the development of the NIS. More precisely, we discuss how different growth rates can be associated with different income elasticities, which are, in turn, determined by the maturity of the NIS. In principle, a mature NIS would imply a higher diversification of the national production, increasing the high technology content sectors share in total output and, thus, directly impacting the pattern of trade. It would favour the exports of technological goods, whose income elasticity is high, and the imports of more basic goods, with lower income elasticity. Moreover, this process would increase the non-price competitiveness of the goods produced in the economy as a whole (changing the sectoral income elasticities of demand), benefiting all sectors exports, although in different degrees.

We then present an econometric exercise assessing the relationship between an indicator of the level of NIS development and the pattern of foreign trade. Assuming that there is a positive

[1] A question that arises, consequently, regards the importance of the production structure and of foreign trade for economic development. This discussion goes back to Prebisch (2000a, 2000b), Furtado (1961) and Kaldor (1996). For the specific analysis of growth, the seminal models were proposed by Thirlwall (1979), which were revised and extended by McCombie & Thirlwall (1994, 2004). Recent empirical tests of balance-of-payments constrained growth models can be seen in Porcile & Lima (2006), McCombie & Britto (2009) and Carvalho & Lima (2009).

[2] See, for example, Jayme Jr & Resende (2009) and Resende & Torres (2008).

relationship between the technological content of a good and its income elasticity of demand, as shown by Gouvêa and Lima (2010), we test the relationship between the Brazilian sectoral exports, classified by its technological content according to Lall's (2001) methodology, and the share of Brazilian patents in the world total (registered under the USPTO). Hence, patents are used as a proxy for the development of the Brazilian NIS. Innovations to the model, by means of impulse response functions and forecast error decomposition, corroborate the results.

The paper comprises three sections besides this introduction. In the next one, we discuss the Kaldorian-Keynesian balance-of-payments constrained growth models and the Neo-Schumpeterian literature related to the National Innovation Systems. The third section presents the methodology used for the tests with the Brazilian data, as well as the results of the estimations. Lastly, we present some concluding remarks.

2. THEORETICAL FRAMEWORK

2.1. The balance-of-payments constraint to growth and the non-price competitiveness

Many studies of Kaldorian-Keynesian background endeavour to analyse the causes of uneven growth among countries. This tradition emphasises the role of demand growth as the ultimate determinant of a country's economic growth rate. In this framework, the balance-of-payments (BOP) becomes the fundamental limit to the growth of an open economy. The exports, in turn, play the dual role of stimulating demand and of providing the foreign currency that allows the other elements of autonomous demand to grow, particularly investment. From a dynamic viewpoint, the stimulus to demand can unleash a virtuous growth cycle that tends to increase the global productivity of the economy, due to the migration of factors to more productive sectors (manufacturing) and to the greater learning-by-doing these sectors will display (Kaldor, 1966).

This is the underlying argument of the balance-of-payments constrained growth models. Thirlwall (1979) demonstrates that long-term growth is directly related to the income elasticities of demand for exports and for imports. The model is composed of three equations:

$$x_t = \eta(p_{dt} - p_{ft} - e_t) + \varepsilon z_t \quad (1)$$

$$m_t = \psi(p_{ft} + e_t - p_{dt}) + \pi y_t \quad (2)$$

$$m_t + p_{ft} + e_t = p_{dt} + x_t \quad (3)$$

Equations (1) and (2) represent the functions of demand for exports and for imports, respectively, both expressed in growth rates. The variable x stands for the growth rate of exports, m for the growth rate of imports, p_d and p_f are the rate of change of domestic and foreign prices, e is the rate of change of the nominal exchange rate, z is the growth of the income of the rest of the world, y is the growth of real output, η (< 0) is the price elasticity of demand for exports, ψ (< 0) is the price elasticity of demand for imports, ε is the income elasticity of demand for exports, and π is the income elasticity of demand for imports. Equation (3) is the BOP equilibrium condition.

Solving the system of equations (1) to (3), we arrive at the BOP equilibrium growth rate (the time subscripts have been dropped for expositional convenience):

$$y_{B1} = \frac{(1+\eta+\psi)(p_{\mathrm{d}} - \mathrm{p_f} - e) + \varepsilon \mathrm{z}}{\pi} \tag{4}$$

This equation leads to many results: i) a domestic inflation higher than the inflation of the rest of the world reduces the BOP equilibrium growth rate, if $|\psi + \eta| > 1$ (Marshall-Lerner condition); ii) a currency devaluation (e>0) tends to increase the BOP equilibrium growth rate, if $|\psi + \eta| > 1$; iii) a faster growth of world income increases the BOP equilibrium growth rate; iv) the higher is the income elasticity of demand for imports (π), the lower will be the BOP equilibrium growth rate. However, by assuming the stylised fact that terms of trade are fixed in the long run (p_{dt} - p_{ft} - e_t = 0), the equation can de reduced to the ratio represented by equation (5), known as Thirlwall's Law:

$$y_{B2} = \frac{\varepsilon}{\pi} z \tag{5}$$

or

$$y_{B3} = \frac{\mathrm{x}}{\pi} \tag{6}$$

It is worth mentioning that equation (5) is also valid if the Marshall-Lerner conditions are just met (i.e., η + ψ = -1), even if there are substantial variations of relative prices. This last equation represents the highest growth rate compatible with BOP equilibrium. A faster growth rate would be met via policies that stimulate increases of the income elasticity of demand for exports and reductions of the income elasticity of demand for exports.

In order to better suit the model to the reality of developing countries, it was expanded so as to include the possibility of financing BOP deficits through capital flows[3]. Relevant though they may be, empirical analyses have shown that the effects of the latter are of secondary importance when compared to the elasticities – especially because the countries cannot indefinitely finance BOP deficits. In fact, regarding the Brazilian case, Britto & McCombie (2009) verified that from 1955 to 2006 the growth of the Brazilian economy was BOP constrained, even when taking into account the effects of capital flows and interest payments. Carvalho & Lima (2009), on the other hand, concluded that the reason between the elasticities fell from 7%, during the 1930 to 1993 period, to but 1.3%, from 1994 to 2004, which highlights that the reduced dynamism of the Brazilian economy during the period was the result of maintaining a productive structure that neglected high technology goods.

Analysing data from Brazil and from the OECD countries, Jayme Jr & Resende (2009) point that one of the difficulties in reducing the Brazilian BOP constraint lies in the fact that the country's balance of trade presents large deficits in goods of medium and high technological intensity since the beginning of the 1990s. According to the authors, this is a reflex of the low development of Brazil's

[3] See, for example, Thirlwall & Hussain (1982), McCombie & Thirlwall (1997), Barbosa-Filho (2001), Moreno-Brid (2003).

NIS. Since the trade liberalisation of the 1990s, technological goods have represented a greater percentage of total imports, while their exports have not increased – and this worsens the country's role in international trade.

Therefore, the importance of the income elasticities for growth suggests a deeper investigation of their determinants. Although the output growth rate is determined by the growth of demand, the balance-of-payments constrained growth approach also considers the importance of the supply side. Nevertheless, it must be mentioned that these characteristics do not refer only to the increase of the stock of factors, but also, to qualitative aspects, related to what has come to be called non-price competitiveness (McCombie & Thirlwall, 2004).

In fact, since the 1930s a major part of the industrial output has been characterised by an oligopolistic competitive environment, in which aggressive price competition is not to be found (McCombie & Thirlwall, 1994). The predominant form of competition is, rather, non-price competition. According to the authors "as countries get richer through time there tends to be a shift of emphasis within sectors towards product novelty, quality and reliability, and in general towards high value-added products where non-price factors are critically important" (McCombie & Thirlwall, 1994, p. 283).[4]

Nonetheless, the lack of non-price competitiveness might just as well be described as a lack of price competitiveness. However, the exclusive focus on price competitiveness entails the necessity of continuous and ever-larger price drops in order to make up for the lack of non-price competitiveness.

Many authors, of different theoretical backgrounds, performed empirical tests with the aim of studying the impacts of non-price competitiveness on foreign trade. In this regard, several types of proxies were used, including, amongst others, the number of patents and R&D expenditures. Some of these studies are based on the theory of the technological gap (Posner, 1961; Hufbauer, 1970; Pavit & Soete, 1980; Mayes, Buxton & Murfin, 1988; Greenhalgh, 1988, 1990; Schott & Pick, 1984; Fagerberg, 1988), while some are based on the product life cycle theory (Vernon, 1966, 1970; Wells, 1969, 1972) or even on the hypothesis of product differentiation and the preference for variety (Linder, 1961; Davies, 1976; Barker, 1977). As a rule, the studies verify the importance of non-price competitiveness for the expansion of exports and, hence, for the growth of income.

The focus on non-price competitiveness, however, goes against the neoclassical assumption that similar goods are homogeneous and would, therefore, follow the "law of one price". Price differences, according to the neoclassical approach, would reflect a differentiation of the compared products. This procedure entirely voids the law of any empirical basis (McCombie & Thirlwall, 1994)[5]. The growth of non-price competitiveness, therefore, chiefly indicates the degree of product differentiation and increases of the quality of national output. Therefore, manufacturing would be more liable to be subject to such competitive gains, for primary goods tend to be more homogeneous.

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[4] Defined as "all those factors other than price that affect consumer choice. These include quality, reliability, speed of delivery, the extent and efficacy of the distribution network and the availability of export credit and guarantees" (McCombie & Thirlwall, 1994, p.265).

[5] The importance given to product differentiation and non-price competitiveness ultimately led some authors to integrate this approach (preference for variety and oligopolistic competition) to the analysis of regional growth (Fujita, Krugman, Venables, 1999; Krugman, 1991).

This is exactly what Kravis & Lipsey (1971) found, demonstrating that basic goods are more prone to price competition than manufactured goods, which display greater differentiation.

It is also important to mention the impact of the exchange rate on competitiveness. Although exchange rate analysis are always controversial, it is worth to mention that according to Breech & Stout (1981), exchange rate devaluations would affect manufactured and basic goods (which are more homogeneous) differently. They argue that a devaluation would positively influence the exports of basic goods, while manufactured ones would be less affected. This would be due to the fact that the profitability of producing manufactured goods is raised with the devaluation, thus discouraging the increase of their quality, which would negatively the exports.

It is clear, however, that exchange rate devaluations improve the position of the balance-of-payments, albeit temporarily. On the other hand, an overvalued exchange rate negatively impacts profits, to the point of possibly preventing national manufacturing from continuing its operations, even if it focuses on non-price competitiveness. In short, although maintaining an overvalued exchange rate can negatively influence growth, as it reduces profitability, an excessive and lengthy devaluation might hinder the national non-price competitiveness, making it more difficult to consistently overcome the balance-of-payments constraint to growth (McCombie & Thirlwall, 1994).

Moreover, when discussing the empirics of competitiveness, it is important to highlight the so-called "Kaldor Paradox" (Kaldor, 1978), which constitutes the stylised fact that many countries that experienced falls of price competitiveness (as happened with Germany and Japan, amongst others) actually increased their share in world trade. Tests of Kaldor's Paradox carried out by Fagerberg (1988) provide a further confirmation of its validity, thus corroborating the importance of non-price competitiveness for the growth of national exports and income.

The conclusion of this debate is that non-price competitiveness is an important factor behind exports, given the preference for variety that grows with income – even if, for the same reason, it does not lead to a reduction of imports.[6] Such form of competition would, therefore, alter the income elasticities of demand for exports and for imports. Nevertheless, it can be assumed that the income elasticity of demand for exports presents a greater variation to changes in non-price competitiveness than the elasticity of imports does.

Theoretically, however, gains from non-price competitiveness can be obtained in any kind of products. Freeman (1979) tests the impact of different non-price competitive strategies on the following sectors: i) capital goods, ii) consumption goods, and iii) basic materials. The results show that, for the production of capital goods, competition focuses on the development of new, more technological, products – which indicates the importance of R&D. In the production of consumption goods, on the other hand, design and marketing play a more important role, while for basic materials most innovations focus on reducing inputs. Thus, prices are more important for consumption goods and basic materials than for capital goods, which leads to the conclusion that sectors with higher

[6] As Barker (1997, cited by McCombie & Thirlwall, 1994, p. 284) puts it, "as real income increases, purchasers tend to buy more varieties of a product, and since a greater number of these varieties is available from abroad rather than from home sources, the share of imports in demand tends to increase". Consequently, a greater level of international intra-industry trade leads to a higher income elasticity of exports and of imports, due to the larger product differentiation thereby generated.

technological intensity are more susceptible to non-price competitiveness (differentiation and greater quality). Their elasticity of demand is, therefore, higher.

Working with this idea, Araújo & Lima (2007) developed a model that leads to what they call the Multi-Sector Thirlwall's Law (MSTL). By considering that each sector of the economy is subject to a different income elasticity of demand for its production, the model implies that shifts in sectoral shares, i.e., shifts in the production structure, affect the growth rate of the economy as a whole. Hence, a country's growth rate can increase even if the rest of the world continues to grow at the same pace, as long as the composition of exports and imports is favourably altered (Gouvêa & Lima, 2010). In sum, the growth rate depends on the sectoral structure of the economy.

In short, the MSTL could be described as follows[7]. If an economy is considered to be composed of many sectors, each one subject to different income elasticity of demand, than we have that:

$$\varepsilon = \sum_{i=1}^{k} \phi_i \varepsilon_i \tag{7}$$

$$\pi = \sum_{i=1}^{k} \theta_i \pi_i \tag{8}$$

Where i denotes the sectors of the economy, ϕ_i and θ_i are each sector's share in total exports and imports, respectively (with $\sum_{i=1}^{k} \phi_i = 1, \sum_{i=1}^{k} \theta_i = 1$). One can notice, therefore, that the overall elasticities are altered by changes in the sectoral composition of the economy. Hence, by substituting (7) and (8) in (5) we find the so called MSTL[8].

$$y_{B4} = \frac{(\sum_{i=1}^{k} \phi_i \varepsilon_i) z}{\sum_{i=1}^{k} \theta_i \pi_i} \tag{9}$$

If we consider that the economy is composed by three sectors, as will be done in the tests presented in this paper, one producing primary goods (PP), one producing low-tech manufactures (LT), and the last one producing high-tech manufactures (HT), than we would have:

$$y_{B4} = \frac{(\phi_{PP} \varepsilon_{PP} + \phi_{LT} \varepsilon_{LT} + \phi_{HT} \varepsilon_{HT}) z}{(\theta_{PP} \pi_{PP} + \theta_{LT} \pi_{LT} + \theta_{HT} \pi_{HT})} \qquad 10)$$

Gouvêa & Lima (2010) estimate the sectoral elasticities for various Latin American and Asian countries. They confirm that the technology-intensive sectors present greater income elasticity, and that the differences in sectoral elasticities are lower for imports than for exports. The authors also

[7] The representation corresponds to an alternative form to the original Araújo & Lima (2007) MSTL specification, which is based on the Pasinettian model rather than the Thirlwall's one.

[8] A more complete specification would be found by substituting (7) and (8) in equations (1) and (2), along with a similar specification for the sectoral price-elasticities. Nevertheless, to reduce the model's complexity we prefer to go directly to the final equation by substituting (7) and (8) in (5).

conclude that both the original Thirlwall's Law and its multi-sector version adequately represent the economy's real growth rate. Lastly, the authors use the share of each sector in foreign trade to calculate the yearly change of elasticities as a weighted average (using the estimated income elasticities of the sectors as the weights), thus capturing the process of structural change. Hence, the tests confirm the importance of increasing the share of high-tech sectors in order to accelerate growth.

2.2. The National Innovation System

Given that the sectoral composition of output and trade are crucial for economic growth, it is important to understand the connection between a country's capacity to innovate and its capacity to economically exploit these innovations.

According to the Neo-Schumpeterian approach, the innovative process is directly related to the concept of the NIS. A term defined by Nelson (1993) and Lundvall (1992), the NIS highlights the importance of institutional arrangements supporting the adoption and the development of innovations. Economic growth, according to this approach, is not entirely determined by the capacity of introducing radical innovations, but also by being able to efficiently spread innovations throughout the economy (Freeman, 1995).

The creation and adoption of innovations are paramount in maintaining economic development, for their introduction makes it possible to obtain extraordinary profits. Thus, as authors such as Abramovitz (1986) and Perez & Soete (1988) argue, in order to close the income gap between and underdeveloped countries, it is necessary to endogenise the process of developing, and productively adopting, innovations. This is the so-called catching-up process, which makes it possible to continuously obtain extraordinary profits and, consequently, increase the accumulation of capital.

According to the Neo-Schumpeterian theory, technical progress can be generated through multiple and interrelated manners. Amongst these interrelations, those between education, technical progress, capital accumulation and learning are of relevance. As Nelson (1964) argues, if more productive technologies require greater knowledge of the workers, then investment in education and technological progress would be highly correlated.

On the other hand, Abramovitz (1986) stresses that there is a lag between the development of an innovation in the central countries, which shifts the frontier of knowledge, and the adoption of this innovation in the peripheral countries. In order to realise the catching-up process, reducing this gap is a crucial point. When peripheral countries quickly adopt innovations, they benefit from them for a longer period, not having incurred in the enormous costs of creating the innovation. The economic gap between the centre and the periphery is thus reduced. Nevertheless, for this process to take place it is necessary to develop a "social capacity" that allows for the quick adoption of technology, which is not only related to an increase of the educational level and to building a scientific infrastructure, but also to the creation of a regulatory and institutional apparatus to support and stimulate this process.

Seeking to define parameters for classifying the maturity of a country's NIS, Albuquerque (1999) created what he called the Opportunity Taking Indicator (OTI). The index is defined as the country's share in the total patents registered under the USPTO, divided by its share of the world's scientific articles indexed by the ISI. The numerator is a proxy for the technological production, while the denominator is a proxy for scientific production. Thus, indicators close to or above one would indicate that the country in question possesses characteristics similar to that of a mature NIS, while low indicators would indicate greater similarity to an immature NIS.

Notwithstanding the fact that mature NISs possess an institutional structure that supports and favours technological and scientific development, it is important to notice that there is no fixed format for a mature NIS. On the other hand, each country thus characterised developed its institutional apparatus according to its historical, social and economic context.

The examples of Japan, the USSR, Latin America and Asia are paradigmatic. While the first two presented extremely high R&D expenditures, only Japan was able to develop an efficient NIS. This demonstrates that directing resources to R&D is not sufficient for guaranteeing that the innovations are commercially successful, thus leading to productivity gains (Freeman, 1995). The fundamental difference between the two systems was that in Japan there was a strong presence of R&D inside the firms, as opposed to the USSR were R&D was located at research institutes and universities. Besides this, in the latter there was little incentive for innovations at the firm level, deterring the productive adoption of the developed innovations.

Regarding Latin America and Asia, Freeman (1995) says that the drop of the Latin American GDP per capita, compared to its continuous growth in Asia, is due to the more radical social reforms carried out in the Asian countries – such as the agrarian reform and the universalisation (and improvement) of education[9]. This argument denotes the importance of factors related to the "social capacity" for creating an efficient NIS.

What stands out from the briefly presented debate is that indicators such as the OTI of Albuquerque (1999), or the number of registered patents per capita in relation to the world total or average, can be good indicators of the maturity of the NIS. Indicators such as R&D expenditures, on the other hand, can present distorted assessments, as indicated by the case of the USSR. Regarding the educational level, although it is of great importance in the Neo-Schumpeterian framework, it is hard to be measured in terms of its quality, while attendance indicators can be distorted for some underdeveloped countries. Indicators using the number of patents, in their turn, can be criticised due to the difficulty and the costs of registering a patent. This may lead to an underestimation of innovative activities, especially in underdeveloped countries. Nevertheless, insofar as they clearly indicate the capacity of producing innovations valuable enough to be patented, we consider here that indices using the number of patents provide a good image of the development of the countries' NISs.

[9] Nevertheless, it is important to emphasize the crucial role that the Latin American debt crisis had in changing the pace and the strategy of growth of the countries of the region.

2.3. National Innovation System and non-price competitiveness

The great external vulnerability verified in underdeveloped countries is an important stylised fact of the world economy. Although peripheral countries experience growth during moments of rising international demand for their products and services, the low technological development of these countries reduces the non-price competitiveness of their exports. This constitutes a *structural* constraint to their growth. It is a situation that directly results from the differences in the income elasticities of demand for different kinds of products (primary, manufactured or highly technological ones). Due to this, even after undergoing a considerable process of industrialisation, many underdeveloped countries were not able to overcome their balance-of-payments constraint to growth.

According to Fajnzylber (1983, 2000), this vulnerability will only be overcome by the creation of an endogenous nucleus of dynamic technological progress, thus providing substantial competitiveness gains. This process would include important changes in the processes of industrialisation in underdeveloped countries, particularly due to the necessity of creating (and expanding) a competitive sector of capital goods. According to the author, this requires, on the one hand, commitments regarding the success of competing technological paradigms, and, on the other, abandoning imitative practices in favour of adaptive and, fundamentally, creative ones.

There is thus a clear relationship between the productive structure of a country and the possible technological paths that can be followed for an effective catching-up process to take place. Nevertheless, the chances of actually exploiting these possibilities largely depend on the R&D efforts and their effective translation into productivity gains. In other words, the association between structural change and greater international competitiveness depends on the level of a country's scientific and technological development.

In this context, as already discussed, Jayme Jr. and Resende (2009) argue that the development of the NIS determines the differences among income elasticities of demand by determining the sectoral composition of each economy. The lower the development of a country's NIS, smaller the diversification of national output, implying the necessity of importing a wider variety of goods. Imports are thus excessively high. Hence, the less developed a country's NIS, the lower the non-price competitiveness of the goods it produces (and the higher the need for imports), worsening its external vulnerability.

Once non-price competitiveness addresses the supply characteristics of the goods produced, it is important to highlight how it affects the sectoral shares of the local economy. Seeking higher profits, firms often try to gain market share by increasing the quality of its production, or introducing product differentiation (i.e. non-price competitiveness). Nonetheless, sectors that produce goods with high technological content are more prone to such changes. As a result, sectoral changes are fostered by the search for greater product diversification. Therefore, higher NIS development is assumed to increase innovations, which indicate to entrepreneurs the possibility of increasing profits through product differentiation and structural change. Finally, once this process is only possible through investment, it is implied that NIS development induces increases in investment in sectors with higher technological content. Increased investment leads to increased high-tech exports and reduced high-tech imports, thus changing the sectoral composition of trade.

Therefore, developing the NIS is paramount for overcoming the balance-of-payments constraint. In sum, by fostering structural change toward sectors that produce goods with high technological content, higher NIS development increases the share of high-tech goods exports, and decreases the share of these goods imports. Furthermore, by improving the non-price competitiveness of the economy as a whole, an efficient NIS would also improve exports of all goods and reduce its imports. The magnitude of these effects, however, would be smaller than the ones impacting high-tech exports and imports. This process changes the shares of each sector in total exports and imports. The result, following the MSTL, is an elevation in the local economy growth rate.

3. EMPIRICS

The Kaldorian literature, represented by the balance-of-payments constrained growth approach, defines that growth is ultimately determined by the income elasticities of demand for exports and imports. Higher growth rates, therefore, are associated with a low income elasticity of demand for imports and a higher income elasticity of demand for exports. Gouvêa & Lima (2010), on the other hand, have asserted that the elasticities differ according to the technological intensity of the goods, being higher for goods with high technological content. The next step, then, is to include the technological upgrading dynamics and its productive application into the analysis. Therefore, through the Neo-Schumpeterian framework the elasticities are made endogenous, becoming directly related to the share of sectors with high technological content in the national output, which, in its turn, is determined by the degree of development of the NIS. With the aim of substantiating this analysis, this work performs some tests seeking to relate the sectoral growth of exports, classified according to their technological intensity, and the growth of the share of Brazilian patents in the world's total – a proxy for the development of the NIS.

The intuition behind the tests is that innovations induce investments in high-tech sectors, which produce goods with higher income elasticity of demand. Nevertheless, since we assume that higher investment in those sectors would lead to higher exports (lower imports) of the goods they produce, we then test directly the relationship between exports (and imports) and innovations. Structural change is therefore implicitly considered[10]. On the other hand, once non-price competitiveness impacts the income elasticities their selves, we choose to estimate an equation with the simple relationship between sectoral imports and exports and the proxy for the level of development of the NIS, excluding national and international income respectively (and terms of trade) so that the elasticities are not held fixed. However, this does not introduce any bias to the estimations, once we perform cointegration techniques.[11]

The tests performed in the following topics use disaggregate data – according to the SITC 2-3 classification – between 1971 and 2007 for Brazilian imports and exports, taken from UNComtrade.

[10] It is important to highlight that we do not consider that supply creates its own demand. We consider that demand provides the incentive for higher production. Seeking sectors with higher demand, firms are driven to high-tech sectors, promoting a structural change of the economy. Hence, innovations are not only an important pre-condition for this process to occur, but they even provide an incentive to it.

[11] It is noteworthy to mention that tests including income and terms of trade presented similar results to the ones presented in this paper.

The technological intensity was classified as proposed by Lall (2001) – Table 2, Annex 1. Based on this classification, we estimated distinct models for each of the imports and exports categories. They were defined as follows: i) manufactured goods of high or medium technological intensity, henceforth Mht and Xht, respectively for imports and exports; ii) manufactured goods of low technological intensity or natural resource-based, henceforth Mlt and Xht; and iii) international commodities, henceforth Mpp and Xpp. The patents data used in the tests were taken from the United States Patent and Trademark Office (USPTO). The period of analysis was chosen due to the fact that data for Brazilian patents registered under the USPTO only encompass the 1971-2007 period.

3.1. Methodology

A group of series is said to be co-integrated to p-q order, or CI(p,q), if: i) all of them are integrated to order p, I(p), and ii) there is a linear combination of them that is integrated to order p-q, with q>0. The first step was, therefore, to test for the stationarity of the series being analysed. Despite being commonly used, the augmented Dickey-Fuller (ADF) statistic is very sensitive to the number of lags included in the model. Moreover, the tests assume as a hypothesis that the residuals of the equation are homoscedastic and serially uncorrelated. Therefore, in the absence of normality of the residuals in the ADF test equation, the Phillips-Perron (PP) test, based on an MA(1) stochastic process, displays better results. The Annex 2 of this work resumes the ADF and PP test statistics for one and for three lags of the series, as well as for their first differences. The choice of the number of lags was based on the normality criterion of the ADF equation residuals. Thus, for one lag the best results are those of the PP statistic, while for three lags the ADF statistic is more powerful. As can be seen, the null hypothesis of non-stationarity is not rejected for all studied variables. For the first differences of the series, however, this same hypothesis is rejected. This shows that they are I(1), or integrated to order 1, allowing us to test the existence of long-term relationships between them.

Since it is a method of easier application (in a single stage), the Johansen procedure (Enders, 2003) was chosen to verify if the series are co-integrated and to estimate their long-term normalized cointegrating vector. The choice of the specifications of the models to be tested was based on the minimisation of the information criteria most used in the literature: Schwartz (SC), Akaike (AIC), Hannan-Quinn (HQ) and the final prediction error (FPE). These criteria were estimated with a lag truncation of 6 – given the reduced degrees of liberty of the models –, and their results are resumed in Annexes 3 and 4. Furthermore, the results of each model's trace statistic (that shows the number of cointegrating vectors in the system) are presented in Annex 5, and the normality tests (autocorrelation and heteroscedasticity) of the residuals of all studied specifications are shown in Annex 6. The results of those tests indicate the validity of the co-integration estimations.

The results for the cointegrating vectors are shown in the next section. For all the models we estimated the following specifications: i) without a constant term in the cointegrating vector, ii) with a trend term in the cointegrating vector, and iii) with a constant term in the cointegrating vector. Nevertheless, only the results for the last model are shown, for it presented more robust results in the tests.

So as to identify the short-term and causality relationships between the variables, we decided to develop a vector error correction (VEC). Given the structure of the VEC to be estimated, it must be said that, differently from the VAR whence it is derived, the OLS estimation is no longer suitable due to the necessity of imposing cross-equation restrictions to the system. Even though its results are not presented, they shall be fundamental for analysing the impacts of innovations of the variables in the system.

We shall use two instruments for analysing the innovations: the impulse response functions and variance decomposition analysis. They shall only be used, however, to analyse the equations involving the exports and imports of goods of high or medium technological intensity, which are the main focus of this paper. The first instrument allows us to simulate the behaviour of the *n* variables over time in the model, by forcing a shock of one standard deviation to the residuals of each variable. This analysis is only possible due to the partial correlation between the residuals of each series of the model, notwithstanding the assumption that any variation of the residuals is caused by exogenous shocks. Given the short convergence interval of the series, the charts of the impulse response functions only encompass a ten-year period. The second instrument, the decomposition of the forecast errors of the model, complements the first, insofar as it allows us to dynamically analyse the behaviour of the variables subjected to shocks, revealing at each period the weight of each residual in the forecast errors of the models. Given the yearly interval of the data and their relatively quick convergence, results selected for the first twenty periods will be outlined.

Nevertheless, it is important to highlight that the results must be looked upon with caution. The analyses of the innovations aim only at confirming the causality of the relations and at trying to corroborate the magnitude of the impacts, since we are seeking long-term relationships, and not short-term ones.

3.2. The technological balance of trade and the Brazilian innovation system

The present section investigates the relationship between the development of the NIS and the Brazilian exports and imports. Through the tests reported here we aim at providing an initial evidence that the NIS development has a direct impact on the sectoral share of the exports and imports of each economy, which would reflect in its growth rate according to the MSTL. As previously indicated, since the studied variables are not stationary, cointegration techniques will be used for estimating the following models[12]:

$$\ln Xi_t = \beta_{01} + \beta_{11} \ln P_t + e_{1t} \qquad (11)$$

$$\ln Mi_t = \beta_{02} - \beta_{12} \ln P_t + e_{2t} \qquad (12)$$

[12] Although that specification excludes other determinants of imports and exports, it does not generate bias in the estimated parameters as long as the two series are co-integrated and we are using time series techniques to estimate the temporal relation between the variables (Enders, 2003).

where *i* denotes the technological intensity classification[13], and P is the number of Brazilian patents divided by the total of world patents[14] – it is an indicator of the maturity of the Brazilian Innovation System. Following the theoretical framework presented in section two, we assume that patents present a positive impact on the exports of high-tech goods, and a negative impact on the imports of those goods. The normalized[15] cointegrating vectors, which refer to an error correction model estimated through the Johansen procedure (Enders, 2003, p. 362), are shown in Tables 1 and 2 (the other test statistics are found in the appendixes). Although we present in the tables the adjustment coefficients, which represent the speed of adjustment of each of the variables to external shocks, we focus our analysis on the interpretation of the normalized cointegrating vectors.

TABLE 1
Normalized Cointegrating Vectors – Exports

Variables	Xht	Xlt	Xpp
Xi	1	1	1
Patents	-2,588452	-1,970190	-1,841032
	0,28896)**	0,30665)**	0,25780)**
Constant	-3,584576	-3,16769	-3,01029
	2,11812)	2,25963)	(1,92681)
Adjust. Coef.			
D(Xi)	-0,179762	-0,16938	-0,17326
	(0,03695)**	(0,03539)**	(0,05876)**
D(P)	0,179298	0,14383	0,21528
	(0,05740)**	(0,05911)**	(0,08395)**

Obs.1: 3 Lags
Obs.2: Standard error in parentheses
** Significant at 5%.
Source: own elaboration.

Observing the magnitude of the estimated parameters in Table 1 it is possible to verify that the greater the technological intensity of the goods, the stronger will be the positive effect of the NIS development on exports of these goods. – it is important to remember that the signal of the tests is interpreted as the inverse of those displayed[16]. Thus, a larger share of Brazilian patents (representing a greater development of the NIS) increases the exports of more technology-intensive goods. For low-tech (Xlt) and primary goods (Xpp), the correlation is positive, but smaller, indicating an uneven effect of the NIS development on the sectoral composition of the economy. However, it is important to

[13] It is of notice that tests made with total imports and exports displayed results similar to those herein presented.

[14] Tests using the number of Brazilian patents registered under the USPTO also presented similar results.

[15] "If (β_1, β_2, … , β_n) is a cointegrating vector, then for any nonzero value of λ, ($\lambda\beta_1$, $\lambda\beta_2$, … , $\lambda\beta_n$) is also a cointegrating vector. Typically, one of the variables is used to *normalize* the cointegrating vector by fixing its coefficient at unity. To normalize the cointegrating vector with respect to x_{at}, simply select $\lambda=1/\beta_1$" (Enders, 2003, p. 322).

[16] Since the error term must be stationary, it follows that the linear combination of integrated variables, i.e., the cointegrating vector, must also be stationary. In our case, from (11) we would have $e_{1t} = Mi_t - \beta_0 - \beta_1 P_t$ (Enders, 2003, p. 320). Hence, negative signs in the vector indicate a positive relationship between the variables. This occurs because "the parameters of the cointegrating vector must be such that they purge the trend from the linear combination" (Enders, 2003, p. 327).

mention that, for the exports of primary goods and patents, the null hypothesis of the existence of a cointegrating vector was rejected in models with 1 or 3 lags. Cointegration was not rejected at 95% with 2 lags, or at 90% with one lag (Annex 5). This result indicates that NIS development does not present strong influence on non-price competitiveness gains in this sector, as it was expected. Therefore, results presented in Table 1 confirm the analysis presented in the previous sections.

Table 2 contains the cointegrating vectors for imports. Regarding the magnitude of the coefficients, despite the fact that the coefficients for goods with medium or high (Mht) and low (Mlt) technological intensity are very similar, they both are significantly larger than the coefficient for the imports of primary goods (Mpp). On the one side, this corroborates the hypothesis that the development of the NIS has a heterogeneous on sectoral imports. On the other side, the similar coefficients observed for goods with low and with medium or high technological intensity could reflect the agents' preference for variety, as previously mentioned. Moreover, the result also confirms that the impact of the development of the NIS is different for exports and imports, being stronger on the former.

TABLE 2
Normalized Cointegrating Vectors – Imports

Variables	Mht	Mlt	Mpp
Mi	1	1	1
Patents	-3,356874	-3,476762	-2,064273
	(0,32327)**	(0,40279)**	(0,42713)**
Constant	-48,263360	-48,55298	-38,23608
	(2,41049)**	(3,00646)**	(3,18733)**
Adjust. Coef.			
D(Mi)	-0,097119	-0,14080	-0,31896
	(0,05536)	(0,04972)**	(0,08268)**
D(P)	0,191958	0,13202	0,08068
	(0,04865)**	(0,04073)**	(0,05167)

Obs.1: 3 Lags
Obs.2: Standard error in parentheses
** Significant at 5%.
Source: own elaboration.

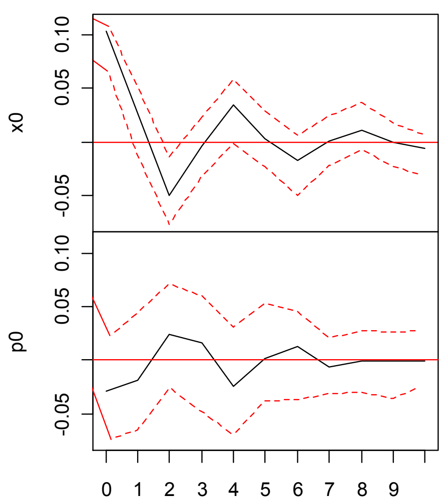
Contrary to our hypothesis, however, the vectors indicate a positive relationship between imports (in general) and patents. In spite of this, in order to substantiate the direction of the causality of the relationship, it is necessary to analyse the impulse response functions and the forecast error variance decomposition. The analysis of these innovations allows for visualising the short-term relationships between the variables, thus determining causality relationships amongst the variables. Paired with the error variance decomposition, it also enables us to analyse the dynamic dissemination of the effects of exogenous shocks on the variables of each model. Though these tests have only been made for the imports and exports of medium or high technological intensity, other tests not presented in this paper have shown that the other analysed series present a similar behaviour.

Moreover, it is important to emphasize that the analysis of the innovations of the model aim only at confirming the causality relationships among the variables of the model, even if the impacts are not very significant. The lags of response of the variables are of minor interest as well.

Figures 1 and 2 show the impulse response function of the relationship between patents and exports, as set forth in equation (11). What stands out is that an increase of exports immediately and negatively impacts the national share of patents. As exports fall, the share of patents once more raises. This result corroborates the cited empirical studies that suggest that an increase of exports (through exchange rate devaluation, for example) can discourage the search for non-price competitiveness gains. This is due to the fact that resources are directed to export-oriented activities, in spite of R&D, during the periods when exports are raised. In Figure 2 it can also be seen that an increase of patents impacts the exports with a lag of one period, as expected.

FIGURE 1

Orthogonal Impulse Response from x0

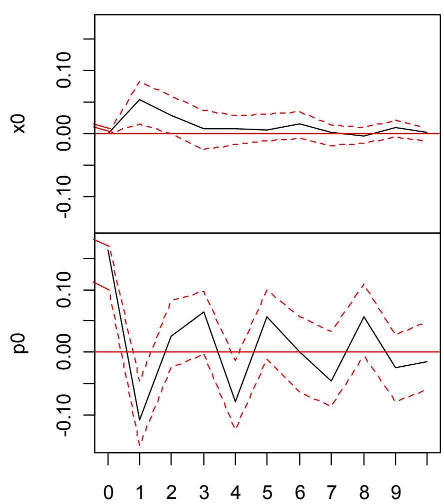


95 % Bootstrap CI, 100 runs

Source: Own elaboration.

FIGURE 2

Orthogonal Impulse Response from p0



95 % Bootstrap CI, 100 runs

Source: Own elaboration.

The analysis of the variance decomposition (Table 3), however, shows that the exports explain only three per cent of the patents variation, which shows that the negative impact seen in the impulse response (Figure 2) is, actually, quite small. Whereas the patents explain 20% of the variation of exports, in strong support of the argument of this work – namely, that a greater development of the NIS raises the exports of goods with medium or high technological intensity, thereby increasing the income elasticity of exports and leading to faster growth.

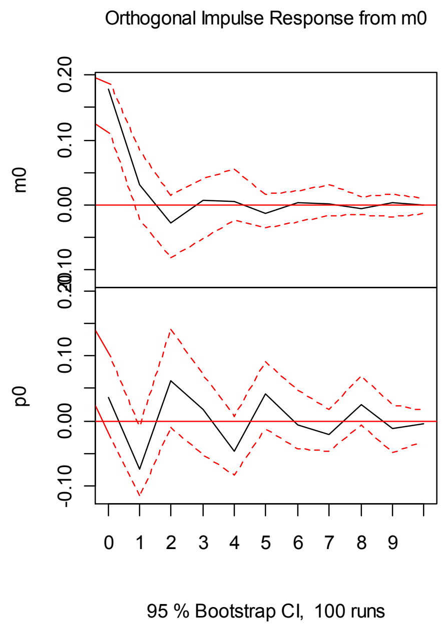
TABLE 3

Decomposition of the variance – patents x exports

Model	Period	Inovations	
		X	p
x	1	1,00	0,00
	2	0,80	0,20
	3	0,79	0,21
	4	0,79	0,21
	5	0,80	0,20
	10	0,79	0,21
	20	0,79	0,21
p	1	0,03	0,97
	2	0,03	0,97
	3	0,04	0,96
	4	0,04	0,96
	5	0,05	0,95
	10	0,05	0,95
	20	0,04	0,96

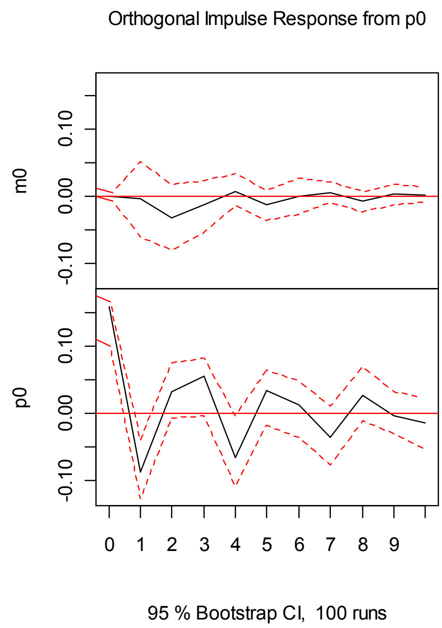
Source: Own elaboration.

FIGURE 3



Source: Own elaboration.

FIGURE 4



Source: Own elaboration.

Figures 3 and 4 depict the impulse response of patents and imports of goods with medium or high technological intensity. Figure 3 shows that a positive variation of the imports immediately and positively impacts the creation of patents. And, as imports fall back, so do the patents. Since a great part of the imports of goods with medium or high technological intensity are capital goods, the result indicates the importance of technology assimilation in the periphery[17]. This increase of patents due to the larger imports of technology-intensive goods is probably associated with the so-called incremental innovations. On the other hand, although an increase of the national share of patents negatively impacts the imports, as expected, it only does so with a two-period lag and the effect is weak. This demonstrates, first, that the Brazilian NIS is still extremely frail, and does not allow for substituting the imports of such goods[18]. In the second place, it confirms the previously mentioned hypothesis of non-price competitiveness focusing on the preference for variety and on differentiation. The analysis of the variance decomposition (Table 4) confirms that the patents do not explain a large share of the variation of the imports, while the imports explain up to 27% of the variation of the patents.

This analysis explains the positive relationship found for the cointegrating vectors, which owes to the fact that importing these goods positively impacts the country's innovations. However, the impact of the increase of patents on the imports is slightly negative, as shown by the impulse response functions and as initially supposed.

TABLE 4
Decomposition of the variance – patents x imports

Model	Period	Innovations	
		M	P
m	1	1,00	0,00
	2	1,00	0,00
	3	0,97	0,03
	4	0,97	0,03
	5	0,96	0,04
	10	0,96	0,04
	20	0,96	0,04
p	1	0,05	0,95
	2	0,17	0,83
	3	0,24	0,76
	4	0,23	0,77
	5	0,24	0,76
	10	0,27	0,73
	20	0,27	0,73

Source: Own elaboration.

These results are in conformity with the non-price competitiveness approach. As argued, the impact of technological innovation is asymmetrical, being higher on exports than on imports. The maintenance of high intra-industry imports reflects the preference for variety and non-price competition – which is also shown by the imports of OECD countries (Jayme Jr. & Resende, 2009).

[17] It is worth mentioning that the PINTEC (*Pesquisa de Inovação Tecnológica*, or Technological Innovation Survey) considers the acquisition of capital goods as innovation.

[18] This situation is verified by the analysis of the data for imports and exports according to their technological intensity, done by Jayme Jr. & Resende (2009).

These results reveal the double effect of the NIS on the elasticities. According to Thirlwall's' Law ($y = \varepsilon z / \pi$), the higher the income elasticity of demand for national exports and the lower the income elasticity of demand for national imports, the faster will growth be. The tests herein conducted demonstrate that, as the technological intensity of national output increases, so does the income elasticity of demand for exports, while the inverse is true for the income elasticity of demand for imports. Nevertheless, what was seen is that the impact of patents is higher on exports than on imports, suggesting not only the frailty of the Brazilian NIS but also the pivotal character of non-price competitiveness.

Therefore, bearing in mind that that the higher the share of sectors with high technological content in national production, the higher the balance-of-payments equilibrium growth rate, then the distinctive conclusion of this study is that the development of the National Innovation System increases the country's capacity of producing goods with high technological intensity, which is a fundamental step of a process of structural change that makes possible the achievement of faster growth rates.

4. CONCLUDING REMARKS

Throughout this paper we have aimed at demonstrating that the National Innovation System relaxes the balance-of-payments constraint on growth by (i) motivating the growth of sectors with high technological content, which elevates overall income elasticity of demand for exports and reduces overall income elasticity of demand for imports according to the MSTL; and (ii) by increasing the sectoral income elasticities their selves. Therefore, by incorporating the Neo-Schumpeterian framework to the analysis, it becomes possible to establish a connection between the elasticities and the productive structure of the economy. Countries with mature NIS are more capable of innovating, thus improving their non-price competitiveness through quality gains and product differentiation. Those countries tend to play a role, in terms of international trade, of supplying goods with medium or high technological intensity, while importing commodities and manufactured goods of low technological intensity. According to the MSTL this sectoral pattern would be associated with higher growth rates compatible with balance of payments equilibrium. The inverse holds for peripheral countries such as Brazil.

In order to substantiate this analysis, we performed a series of empirical tests. We studied the relationship between the level of development of the Brazilian National Innovation System – seen through the Brazilian share in the total world's patents – and its trade pattern. The results suggest that a greater development of the NIS stimulates the exports of goods with medium or high technological intensity, while reduces the imports of such goods. It was also found that the magnitudes of these effects are not symmetrical: the impact of NIS development on exports is greater than that on imports. At this preliminary stage of the analysis, the result can be attributed to the incapacity of the national production satisfactorily substituting the imports of goods with medium or high technological intensity. This is not only directly related to the yet low development of the Brazilian NIS, but also to the non-price competitiveness characteristic, which is based on the preference for variety and on diversification.

In short, the greater development of the NIS provides an incentive to structural change towards sectors of greater technological intensity, and is supposed to increase the sectoral income elasticities throughout the economy. More susceptible to non-price competitiveness, their income elasticity of demand is higher. According to the theoretical framework analysed in the paper, the progressive modification of the elasticities would be an important way of combining economic growth and development. This is due to the fact that the expansion of output would be associated with qualitative improvements of the production that would in turn guarantee new expansions of the exports.

This paper, therefore, presents a contribution to understanding the dynamics of economic growth, insofar as it highlights the relevance of the NIS as a form of influencing the elasticities and thus relaxing the balance-of-payments constraint to growth. Holding as the fundamental reference the importance of maintaining the growth of demand in order to stimulate faster growth, it was shown that the incorporation of technology to the production is central to the continuity of this process and to escaping balance-of-payments problems. For this, it is imperative to build an adequate institutional framework, which is to say, an efficient National Innovation System.

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ANNEXES

ANNEX 1
Aggregation of UNcomtrade data

PP		PPBM			LTM		MTM		HTM
1	268	12	628	688	611	692	781	721	716
11	271	14	633	689	612	693	782	722	718
22	273	23	634		613	694	783	723	751
25	274	24	635		651	695	784	724	752
34	277	35	641		652	696	785	725	759
36	278	37	281		654	697	266	726	761
41	291	46	282		655	699	267	727	764
42	292	47	286		656	821	512	728	771
43	322	48	287		657	893	513	736	774
44	333	56	288		658	894	533	737	776
45	341	58	289		659	895	553	741	778
54	681	61	323		831	897	554	742	524
57	682	62	334		842	898	562	743	541
71	683	73	335		843	899	572	744	712
72	684	98	411		844		582	745	792
74	685	111	511		845		583	749	871
75	686	112	514		846		584	762	874
81	687	122	515		847		585	763	881
91		233	516		848		591	772	
121		247	522		851		598	773	
211		248	523		642		653	775	
212		251	531		665		671	793	
222		264	532		666		672	812	
223		265	551		673		678	872	
232		269	592		674		786	873	
244		423	661		675		791	884	
245		424	662		676		882	885	
246		431	663		677		711	951	
261		621	664		679		713		
263		625	667		691		714		

Source: Own elaboration.
Obs: Goods classification according to SITC
Based on Lall (2001), Competitiveness, Technology and Skills. Cheltenham, United Kingdom: Edward Elgar.
Obs: PP=Primary products; PPBM=Primary producs based manufactures;
LTM=Low-tech manufactures; MTM=Medium-tech manufactures; HTM=High-tech manufactures.

ANNEX 2

Unit Root Tests

Variable	Deterministic Terms	ADF		PP		Critical Values		
		p = 1	p = 3	p = 1	p = 3	1%	5%	10%
ln exports - medium and high technology (Xht)	Constant	-3,3928	-1,6306	-2,4835	-2,4958	-3,6	-2,9	-2,6
	constant, trend	-1,7285	-1,3239	-1,0913	-1,0937	-4,2	-3,5	-3,2
	no constant or trend	3,4086	1,4461	-	-	-2,6	-2	-1,6
p-valor ∆ ln exports (∆Xht)		-4,0831	-2,1703	-7,5037	-6,4918	-3,6	-2,9	-2,6
ln exports - low technology and PPBM (Xlt)	Constant	-1,5463	-1,4435	-1,7223	-1,7207	-3,6	-2,9	-2,6
	constant, trend	-1,9023	-1,5597	-1,4776	-1,4891	-4,2	-3,5	-3,2
	No constant or trend	2,4001	2,1264	-	-	-2,6	-2	-1,6
p-valor ∆ ln exports (∆Xlt)		-4,552	-2,508	-4,1562	-3,9967	-3,6	-2,9	-2,6
ln exports - commodities (Xpp)	Constant	-0,1897	-0,388	-0,1508	-0,1512	-3,6	-2,9	-2,6
	Constant, trend	-1,5201	-1,8119	-1,507	-1,5691	-4,2	-3,5	-3,2
	No constant or trend	3,4335	2,3967	-	-	-2,6	-2	-1,6
p-valor ∆ ln exports (∆Xpp)		-4,7922	-1,6117	-6,2379	-6,1631	-3,6	-2,9	-2,6
ln imports - medium and high technology (Mht)	Constant	-1,0652	-1,9014	-0,5777	-0,5922	-3,6	-2,9	-2,6
	Constant, trend	-2,2985	-3,1387	-1,9597	-2,1476	-4,2	-3,5	-3,2
	constant or trend	2,8889	2,6019	-	-	-2,6	-2	-1,6
p-valor ∆ ln imports (∆Mht)		-4,5227	-2,7473	-5,3069	-5,2477	-3,6	-2,9	-2,6
ln imports - low technology and PPBM (Mlt)	Constant	-0,6095	-1,448	-0,6711	-0,6522	-3,6	-2,9	-2,6
	constant, trend	-2,6197	-3,0147	-2,4366	-2,4935	-4,2	-3,5	-3,2
	no constant or trend	2,3578	2,4985	-	-	-2,6	-2	-1,6
p-valor ∆ ln imports (∆Mlt)		-5,0339	-3,2973	-5,9736	-5,8637	-3,6	-2,9	-2,6
ln imports - commodities (Mpp)	Constant	-0,9294	-1,2343	-0,9105	-0,8048	-3,6	-2,9	-2,6
	Constant, trend	-2,1366	-1,4751	-2,2766	-2,1473	-4,2	-3,5	-3,2
	No constant or trend	1,9646	2,641	-	-	-2,6	-2	-1,6
p-valor ∆ ln imports (∆Mpp)		-5,8363	-3,7605	-7,0592	-7,2128	-3,6	-2,9	-2,6
ln patents (p)	Constant	-2,7668	-1,8799	-3,463	-3,4584	-3,6	-2,9	-2,6
	Constant, trend	-4,388	-3,1122	-5,594	-5,5785	-4,2	-3,5	-3,2
	No constant or trend	-2,1557	-1,575	-	-	-2,6	-2	-1,6
p-valor ∆ ln patents (∆ p)		-7,8001	-2,6205	-10,076	-10,81	-3,6	-2,9	-2,6

Obs1: Critical values of the tests ADF are those reported in Dickey and Fuller (1981) and Hamilton (1994).
Source: Own elaboration.

ANNEX 3
VAR's lag selection – Exports

Xht				
Lag	AIC(n)	HQ(n)	SC(n)	FPE(n)
Trend	4	4	3	4
Intercept	3	3	1	3
Trend and intercept	3	1	1	3
None	4	4	4	4
Choice	3 or 4 lags			
Xlt				
Lag	AIC(n)	HQ(n)	SC(n)	FPE(n)
Trend	3	3	1	3
Intercept	3	3	1	3
Trend and intercept	2	2	2	2
None	3	3	3	3
Choice	3 lags			
Xpp				
Lag	AIC(n)	HQ(n)	SC(n)	FPE(n)
Trend	4	4	1	4
Intercept	1	1	1	1
Trend and intercept	5	1	1	4
None	3	3	1	3
Choice	1 lag			
Obs: lag max = 6				

Source: Own elaboration.

ANNEX 4
VAR's lag selection – Imports

Mht				
Lag	AIC(n)	HQ(n)	SC(n)	FPE(n)
Trend	2	2	1	2
Intercept	2	2	2	2
Trend and intercept	2	2	1	2
None	3	2	2	3
Choice	2 lags			
Mlt				
Lag	AIC(n)	HQ(n)	SC(n)	FPE(n)
Trend	3	3	1	3
Intercept	4	3	1	4
Trend and intercept	4	2	1	4
None	3	3	2	3
Choice	3 or 4 lags			
Mpp				
Lag	AIC(n)	HQ(n)	SC(n)	FPE(n)
Trend	3	2	1	3
Intercept	4	2	2	4
Trend and intercept	1	1	1	1
None	3	2	2	3
Choice	1 to 4 lags			
Obs: lag max = 6				

Source: Own elaboration.

ANNEX 5
Cointegration tests

H0	Statistics of the test			Critical Values		
	lag = 1	lag = 2	lag = 3	90%	95%	99%
Xht						
R = 0	28,1	19,17	15,27	17,85	19,96	24,6
R = 1	11,24	3,84	3,87	7,52	9,24	12,97
Xlt						
R = 0	25,85	21,8	20,42	17,85	19,96	24,6
R = 1	10,55	6,99	4,79	7,52	9,24	12,97
Xpp						
R = 0	19,73	20,05	9,39	17,85	19,96	24,6
R = 1	5,35	7,8	3,92	7,52	9,24	12,97
Mht						
R = 0	36	24,63	28,08	17,85	19,96	24,6
R = 1	4,65	3,55	7,01	7,52	9,24	12,97
Mlt						
R = 0	33,22	25,15	32,03	17,85	19,96	24,6
R = 1	3,55	3,32	11,64	7,52	9,24	12,97
Mpp						
R = 0	25,83	24,03	21,93	17,85	19,96	24,6
R = 1	6,47	4,79	4,88	7,52	9,24	12,97

Obs1: results refer to the best model: only constant in the cointegration vector.
Obs2: results refer to the trace test.
Obs3: R = number of cointegrating vectors.
Obs4: Statistic greater than the critical values mean that the null hypothesis of existence of R cointegrating vectors is rejected.. Thus, if the statistic of the test is greater than the critical value for R=0, but smaller than the critical value for R=1, there is only one cointegrating vector for the variables under analysis.
Source: Own elaboration.

ANNEX 6

Diagnostic of residuals

Model	JB	p-valor	Q	p-valor	ARCH	p-valor
Xht						
lag = 3	1,08	0,8974	36,4332	0,9244	14,4443	0,6997
lag = 2	3,9073	0,4187	38,3255	0,9473	4,4453	0,9995
lag = 1	3,0735	0,5456	50,4765	0,7481	11,2545	0,8832
Xlt						
lag = 3	1,0713	0,8988	27,6857	0,9956	17,1211	0,5148
lag = 2	2,8818	0,5778	29,5951	0,9972	17,1317	0,5141
lag = 1	3,3508	5,01E-01	41,6954	0,9475	13,905	0,7353
Xpp						
lag = 3	10,7472	0,02956	28,3352	0,9942	9,6467	0,9428
lag = 2	4,8562	0,3024	32,9988	0,9892	15,5919	0,621
lag = 1	6,4153	1,70E-01	44,8416	0,8971	10,7575	0,9044
Mht						
lag = 3	1,8207	0,4024	35,1853	0,9442	26,9746	0,07947
lag = 2	2,8228	0,5879	35,8017	0,9734	11,8251	0,8561
lag = 1	2,1818	0,7024	43,1879	0,9265	11,6085	0,8668
Mlt						
lag = 3	3,8946	0,4205	35,818	0,9347	15,839	0,6038
lag = 2	0,8601	0,9302	33,4312	0,9875	13,717	0,7473
lag = 1	2,4671	6,51E-01	40,568	0,9602	34,9238	0,00966
Mpp						
lag = 3	39,677	5,05E-08	30,2143	0,988	30,1639	0,03588
lag = 2	77,5454	5,55E-16	36,049	0,9714	30,6334	0,03173
lag = 1	97,4358	2,20E-16	41,1064	0,9545	26,9745	0,07948

Jarque-Bera (JB): test of normality of the residual (H0: residuals are normal)
Portmanteau (Q): test of autocorrelation of residuals (H0: no autocorrelation)
ARCH: test of heterocedasticity of residuals (H0: homocedasticity)
Obs1: Results refer to the best model: only constant in the cointegration vector.
Source: Own elaboration.